The 1998 Yangtze Flood and Harnessing of the Yangtze River

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Abstract

In 1998, another basin wide extraordinary flood occurred on the Yangtze River following the last one in the year of 1954. The major cause of the 1998 flood was the oversized storm rains. Compared with the 1954 flood in terms of the maximum peak discharge and the maximum 60-day flood volume below Jingjiang river reach, the 1998 flood was smaller than the 1954 one as a whole. The 1998 flood ranked the second among the three basin wide heavy floods (the 1931, 1954 and 1998 floods) occurred in this century on the Yangtze River. However, the flood stages on the middle and lower reaches in the 1998 flood were much higher than the observed ones in the 1954 flood. The major causes for the higher water levels in 1998 were as follows. Firstly, the flood volumes diverted from the river channel through flood diversion and retention in 1998 were much less than that in 1954. In 1954, a total of 102.3 billion cubic meters of flood volume were diverted from the river channel through flood diversion planned and dyke collapse and breaches. If all these floods had been returned to the river channel, the actual flood stages would have been much higher in the 1954 flood. At Luoshan station, for example, the stage would have been 2m higher than the observed one. Secondly, the flood regulation and storage capacities of the lakes have been lowering. Since the year of 1954, the areas of lakes connected with the River in the middle and lower Yangtze have reduced 10,000 square kilometers. The flood storage capacities of Dongting and Poyang lakes have decreased over 18 billion cubic meters due to sedimentation and enclosure of lakeland for cultivation. The flood regulation and storage capacities of the lakes should affect the flood stages to the extent of 1m. The 1998 extraordinary flood has warned us that the capacity to prevent flood and drought disasters in the Yangtze valley has not been strong enough as a whole, and that the flood management planning and flood control works construction shall be improved and strengthened. That is to say, the comprehensive flood control and river harnessing planning shall be perfected; the flood control investment shall increase with a view to carry out the constructions planned in *the Yangtze Valley Comprehensive Utilization Planning*; the management and supervision of flood control works construction in the valley shall be further strengthened, and the water administration be carried out with more force.

1❄ Flow Regime of the 1998 Flood

Note: 1. Professor

1.1 Weather conditions and storm rains

1.1.1 Weather conditions

In the summer of 1998, the longitudinal atmospheric circulation was dominant in the high altitude. In regions of the middle and high latitudes, there existed blocking conditions formed by two high-pressure ridges for a relatively long time, and the cold airs were very active. The subtropical high was strong and its activity presented clear periodicity. The tropical storms appeared significantly less and weaker than usual. Because both the subtropical high and the westerly circulation were stable, with the

confrontation of cold and warm airs, stable heavy storm rain belts formed over the Yangtze valley. In the middle of the summer, the subtropical high retreated to the south and stayed there, which made the ending of the rain season in the middle and lower Yangtze be over 20 days later than usual.

1.1.2 Storm rain process

The storm rain process in the 1998 flood season in the Yangtze valley could be divided into four phases. The first phase was from June 12 to June 26, during which storm rains occurred mainly over the middle and north regions to the south of the Yangtze. The second phase lasted from June 27 to July 15. With the subtropical high extended to the west and the north, the storm rain zone moved northwest to the upper Yangtze region. The third was from July 20 to July 31. As a result of the retreat of the subtropical high to the south, an unprecedented unbroken succession of storm rains occurred along the middle Yangtze and over the northern part to the south of the Yangtze River. The fourth phase was from August 1 to August 29, during which the subtropical high extended for the second time to the north and the west. The storm rain zone was located mainly to the east of the Yangtze in the upper reach and to the west of the Yangtze in the middle reach. Several storm rains occurred in the Jialingjiang, Lishui, Qingjiang, and Hanjiang river basins and in the Three Gorges interval region in the Yangtze.

Statistics showed that the areal rainfall amount in the valley from June to August was 670 mm, which was 37.5 percent larger than usual and just 36mm less than that of the period of 1954 flood. In the upper Yangtze, the areal rainfall amount was 677 mm, 28mm larger than that of the 1954 flood.

The major characteristics of the storm rains were as follows.

(1) **The storm rains occurred frequently**. From June to August, there were 74 days on which storm rains fell. Of which, 64 days witnessed heavy storm rains, accounting for 86 percent of the total number of rainy days. There were 18 days on which extraordinary heavy storm rains fell, accounting for 24 percent.

(2) **The storm rains covered large areas**. The largest coverage area by heavy storm rain with a daily rainfall amount of 100mm was 50,560 square kilometers, which fell on June 13 over Dongting and Poyang Lake water systems.

(3) **The storm rains lasted for long duration**. From June 11 to June 26, the heavy storm rain belt was located in Dongting and Poyang Lake water systems. It stayed there for as long as 16 days. From June 27 to July 16 the heavy storm rain belt moved to the upper Yangtze region, and lasted for 20 days. From July 20 to July 31, the heavy storm rain belt returned to the Dongting and Poyang Lake water systems and remained there for 15 days. From August 1 to August 29 heavy storm rains appeared again in the upper Yangtze region. Storm rains ranking from 'heavy' to 'extraordinary heavy' paced up and down in the upper Yangtze region and the Hanjiang river basin, with duration of 29 days.

(4) **The storm rain intensities were high and the rainfalls were concentrated.** During the period from June to August, there were 1,683 stations (times) that experienced rainfalls with a daily amount ranging from 50 to 99mm, 488 stations with 100 to 199mm, 39 stations with more than 200mm and two stations with over 300mm.

(5) **The rain belts paced up and down between the north and the south and from the lower reach to the upper and vice versa**. In the later 20 days of June, the

rain belt was located mainly in the middle and lower reaches, particularly in Dongting and Poyang Lake water systems. In the first half of July, the rain belt moved to the upper reach region, while in the later half of July, the rain belt returned to the middle and lower reaches. During the first 15 days of August, the rain belt moved time again to the upper Yangtze region, while in the period from 16 to 18 of August, the rain belt was positioned over the middle and lower reaches and in the region to the south of the Yangtze River. From 19 to 25 of August, the rain belt moved to Jialingjiang and Mingjiang river basins and Hanjiang river basin. From 26 to 29 of August, the rain belt shifted again to the middle and lower reaches and the regions to the south of the Yangtze. That the rain belt paced up and down between the south and the north and from the lower reach to the upper and vice versa had resulted in the interaction of floods from the upper, middle and lower reaches in a manner leading to the worst disasters.

1.2 Characteristics of the flood

In 1998 a basin wide extraordinary flood occurred in the Yangtze River valley. At Yichang station on the main stem, there appeared altogether 8 flood peaks. On the 360km of river reaches on the main stem from Shashi to Luoshan and from Wuxue to Jiujiang in the middle reach, and in Dongting and Poyang lakes, the water levels exceeded the historical records several times, with the excesses ranging from 0.55 to 1.25m. The water levels exceeding the historical records remained for over 40 days. At Shashi station, the water levels overrun the historical records for three times and the maximum flood stage surpassed the insuring stage by 0.22m.

The 1998 Yangtze flood was characterized as follows.

(1) ❄ **The interaction of floods was in a manner that resulted in the worst disasters and the floods from the upper reach superimposed over that from the middle reach**. The heavy storm rains in Dongting and Poyang Lake water systems from the second ten days to the end of June had made the stages of the lakes rise sharply. When these floods joined the river, flood stages on the main stem in the middle and lower reaches rose subsequently. As a result, flood stages on the river reaches below Jianli started to exceed the warning stages on June 28. On July 2, the first flood peak at Yichang in 1998 appeared. On this very same day, the flood stage at Shashi surpassed the warning stage. Henceforth, all the water levels on the river reaches below Yichang exceeded the warning stages. On the main stem of the middle and lower Yangtze River, the inflow from the upper reach were rushing to the downstream, while the flows were jacked by the flows from the lower reaches. In the meantime, heavy rains were still covering Sichuan province in the upper Yangtze. On July 18, the second flood peak at Yichang formed. On its way downstream, this peak flood was superimposed over by the floods from Lishui, Yuanshui rivers of Dongting Lake water system, and that from the Chang River of Poyang Lake water system. In the days that followed, another six peak floods occurred successively at Yichang, which made the flood stages on the middle and lower reaches remain high for a long time.

(2) ❄ **The flood stages rose sharply.** As a result of heavy rains in Dongting and Poyang Lake water systems, water levels on the main stem of the middle and lower reaches rose sharply. At the major stations of Lianhuatang, Luoshan, Hankou, and Datong, water levels began to rise on June 13. It took some 15 days for water levels to reach the corresponding warning stages. The average daily rising rate of water levels ranged from 0.40 to 0.43m, with the maximum rate

reaching 0.76 to 0.83m.

(3)❄**The flood stages were high and the duration of high water levels was long**. Among the major stations on the main stem of the middle and lower Yangtze, the maximum flood stages at all the other stations except Hankou, Huangshi and Datong exceeded their corresponding historical records and these flood stages lasted for 10 to 42 days. At most of these stations, the maximum flood stages surpassed the corresponding design water levels.

(4)❄**The flood volumes were large.** The maximum peak discharge at Yichang was 63,300 cubic meters per second. Calculated in terms of flood frequency, this flood could be considered as the 6 to 8 years flood in return period. This peak flood was a little bit smaller than that of the 1954 flood. The maximum flood volume in 30 days was 137.9 billion cubic meters, which was comparable to the 138.7 billion cubic meters in the 1954 flood. The maximum flood volume in 60 days in the 1998 flood was about 10 billion cubic meters larger than that in the 1954 flood. The maximum flood volumes in 30 days at Hankou and Datong stations were 175.4 and 202.7 billion cubic meters respectively, which were smaller than the corresponding flood volumes of 208.7 and 233.8 billion cubic meters in the 1954 flood. The values of the 1954 flood were estimated by returning all the diverted flood volume to the river channel. Calculated in terms of empirical flood frequency, the maximum flood volume in 30 days at Hankou station could be considered as that of the 30-year flood in return period.

1.3 Analysis and conclusions

1.3.1 Major causes of the Yangtze 1998 extraordinary flood

The major causes of the 1998 extraordinary flood on the Yangtze were the oversized storm rains and the reduction in flood regulation and detention capacities of river channels and lakes. The later had led to the lowering of the capacities of channels and lakes to cut flood peaks and the elevating of water levels. The Yangtze is a storm flood river, the floods of which are produced mainly by storm rains. In 1998, before the flood season began, the river channel had already received more water due to the unusual rainfalls. During the period from June to August, the average areal rainfall amount in the valley was 670mm, which was only 36mm less than that of the 1954 flood and ranked the second in the observed precipitation record. The rainfall amount in the upper Jinshajiang River, the Jialingjiang River and the Three Gorges interval region was even more than that of the 1954 flood.

1.3.2 Magnitude of the floods

On the main stem of the Yangtze, the major control stations are Yichang, Hankou and Datong of which the maximum peak discharge were 63,300, 71,100 and 82,300 cubic meters respectively in the 1998 flood. The corresponding water discharges of the 1954 flood were 66,800, 76,100 and 92,600 cubic meters respectively. The maximum discharge of the 1998 flood was smaller than that of the 1954 flood.

In terms of the maximum 30-day flood volumes, the volume at Yichang in the 1998 flood was comparable to that of the 1954 flood. The total inflow in 30-day at Hankou in the 1998 flood was 188.5 billion cubic meters, which was some 30 billion cubic meters less than that of the 1954 flood. (Using the total inflow, we can eliminate the effect of flood diversion and dyke collapse and breaches on the calculation of flood volume.) The maximum 30-day flood volume at Datong in the 1998 flood was 219.3 billion cubic meters, which was about 20 billion cubic meters less than that of the

1954 flood.

The above analysis showed that the 1998 flood was smaller than the 1954 flood as a whole. Among the three basin wide heavy floods occurred in this century in the Yangtze valley, the 1998 flood ranked the second (the other two were the 1931 and 1954 floods). However, due to the effect of natural factors and human activities, the flood stages of the 1998 flood were much higher.

1.3.3 Causes of high flood stages on the middle and lower Yangtze in the 1998 flood

In 1998, the flood stages on the middle and lower Yangtze were much higher than that observed in the 1954 flood. The major causes were as follows. _ In the 1998 flood, the flood volumes diverted from the river channel through planned flood diversion and dyke collapse and breaches were much smaller than that in the 1954 flood. In 1954 a total of 102.3 billion cubic meters water had been diverted from the river channel by flood diversion and dyke collapse and breaches. If all these flood had been returned to the river channel, the flood stages in the 1954 flood would have been much higher. Take Luoshan station for an example. The flood stage at this station would have been two meters higher than the observed one. _ The flood regulation and detention capacities of the lakes have been lowering. Since 1954, the areas of the lakes connected with the River in the middle and lower reaches have reduced some 10,000 square kilometers. The flood storage capacity of Dongting Lake has decreased 10 billion cubic meters duo to sedimentation and enclosure of lake land for cultivation, as far the Poyang Lake, the decrease of the lake storage volume has been more than eight billion cubic meters. The flood regulation and storage capacities of the lakes would affect the rise or fall of the flood stages to the extent of about one meter.

2 Flood Control Preparations and Flood Fighting in 1998

2.1 The preparations before the flood season started were concrete and effective.

In view of the anomaly in climate during the winter months of 1997 and the spring months in 1998, the Changjiang (Yangtze) Water Resources Commission (CWRC) organized in February of 1998 serious analysis on the occurrence and development of flow and rainfall regime, from points of view of the El Nino effect, the ocean environment, the atmospheric circulation, the thermal status of the Qinghai-Tibet Plateau, and the antecedent flow and rainfall characteristics. The conclusion had been drawn that there would appear basin wide heavy flood in 1998 on the Yangtze. Under unified arrangements of the Ministry of Water Resources (MWR) and the State Flood Control and Drought Prevention Headquarters (SFCDPH), various meetings and discussions were organized in time and overall arrangements made. Several work examination groups were dispatched to examine flood control preparations in various Provinces along the river, and put into effect of flood control measures. The administration-chief-responsibility for flood control was emphasized. The flood regulation schemes were adjusted and sent to the related departments and various flood management schemes were worked out. The flood control investment was raised to repair and renovate a large quantity of dangerous hydraulic structures, dangerous river dykes, dangerous reservoirs and dangerous sluice gates before the flood season. The materials for flood fighting were reserved. All this had laid a solid foundation for winning victory over the flood.

2.2 The hydrological forecasts had been accurate and in time

During the flood season, hydrological departments under the CWRC had issued by telegrams flow regime forecasts for over 30,000 stations/times, and 1,300 telegrams of rainfall forecasts. At the same time, they had sent out various flood briefings, flow regime bulletins, important flow and rainfall reports, the quantity of which had created a historical record. Fairly accurate forecasts for several heavy rain flood processes, the transitional weather processes, and the start times to reach the control water levels at important stations on main stem of the middle and lower reaches had been made. Fairly accurate forecasts for the eight peak floods had been issued, which won time for making arrangements to fight the floods and rushing to deal with the emergencies.

2.3 The decision-making for flood regulation had been resolute and correct.

The regulation of the 1998 flood could be divided into three phases. The first phase was from June 11 to July2, on which the first peak flood at Yichang occurred. The second phase started on July 3 and ended on August 6, the day before the fourth peak flood at Yichang appeared. The third phase was from August 7 to August 31, on which the eighth peak flood at Yichang occurred.

During the entire flood regulation process, the Changjiang Flood Control and Drought Prevention Headquarters (CFCDPH) and the CWRC had from the start to the end adhered to the essence of the directions and carried out correctly the directions from the Party Central Committee (PCC), and fully comprehended the PCC's policies for fighting flood and dealing with emergencies. In the light of the flow characteristics of different phases, the corresponding flood regulation schemes were worked out. During the second and third phases, with a view to realize the 'three-insuring', the arrangements to use flood retention and storage areas had been made, evacuating the people living in flood retention and storage areas and in polders endangered by flooding, carrying out lifesaving measures and making absolute sure the people should be safe, in the meanwhile to fight against the flood to the last to prevent the main dykes from collapsing.

2.4 No pains had been spared in fighting the flood and rushing to deal with emergencies.

The flood fighting and emergencies handling could be considered as an intelligence battle against the flood in a sense. During the entire flood season, more than 30 working groups and expert panels were dispatched by the SFCDPH, the MWR and the CFCDPH to the flood-fighting front to give technical assistance. New technologies had played an important role in flood fighting and emergencies handling. The computer networks, the meteorological satellite communications system, the automatic hydrological telemetry systems, the remote sensing systems, and the satellite positioning systems had been applied to flood fighting and emergency handling.

The flood fighting and emergencies handling in the Yangtze valley had been supported by many units all over the country. The departments of material supply, transportation, power supply, sanitation, propagandizing, and public security had spared no efforts to support the fighting against the flood in the Yangtze valley.

2.5 The flood control had been carried out in accordance with the law.

At the critical occasion of flood control, Jiangxi, Hunan, Hubei, Jinagsu, and Anhui

Provinces had declared to enter into emergent flood control state according to the *Flood Control Law*. The flood control commanding departments had in accordance with the Law expropriated flood control materials and tools, cleared the barriers on the flood route, and penalized with a heavy hand the persons who had neglected on their duties of flood control. Every sector, every unit and the public had performed flood control duties self-consciously. It had been proved that the *Flood Control Law*, which came into effect on January 1,1998, and is the first law for natural disaster prevention and reduction in China, had play an important role in the flood control in 1998.

2.6 The existing water works had contributed a lot to flood fighting and emergencies handling.

In the course of fighting the severe flooding, the Yangtze flood control system developed since the foundation of New China had produced significant benefit of disaster reduction. The construction of dykes and embankments, the river course regulations had paid off. In particular, the important dykes basically satisfying the flood control standards laid out in *the Yangtze Valley Comprehensive Utilization Planning* had stood the test of the flood—the flood stages were high while the occurrence of dangerous status was significantly less. The reservoirs had played a great role at the moment of truth and endured the severe flooding. If there had been no hydraulic structures as the physical foundation, we would have not been able to win the whole victory over the 1998 flood.

3 Strategies and Measures to harness the Yangtze River

Though we have achieved glorious victory in fighting against the flood in 1998, we should carefully analyze and sum up the existing problems and lessons at the same time as summing up the achievements and experiences. The serious flood in 1998 rings the alarm for us again. From an overall perspective, the Yangtze River is still low in capacity to resist serious flood, it is very urgent to improve and strengthen the valley flood control planning(FCP) and the construction of flood control projects.

3.1 Improve the YRB flood control and harnessing planning so as to provide guidance for the construction of flood control projects

The practices over several decades and the repeated studies and proofs of various opinions and schemes all have demonstrated that the FCP is the very accordance and basis for the construction of flood control projects. Therefore, CWRC has always been attaching great importance on the FCP of the Yangtze River Basin(YRB). As early as in 1959, the “Report on Main Points in Comprehensive Utilization of the Yangtze River Basin” prepared by CWRC has provided comparatively systematic planning for the flood control constructions of the YRB. The FCP in the report was further improved systematically in 1972 and 1980. In 1990, CWRC compiled the “Brief Report on the Comprehensive Utilization of the YRB”, which conducted systematic enlargement and updating for the FCP of the YRB and has been approved by the State Council. Later in 1992, the “Report on the Planning of the Flood Storage and Flood Control Projects in the Middle and Lower Reaches of the Yangtze River(version for examination)” was compiled. In this report, the main ideas consist of, according to the “high peak and large discharge” characteristic of the Yangtze flood and the natural conditions and socio-economic situation of different regions, the flood control of the Yangtze River must adopt the comprehensive harnessing policies of “Both storage

and discharging should be planned, giving priority to discharging" and "Store in the upper reach and dredge in the lower reach, the problems both on the surface and in the root should be tackled". Through various engineering measures, such as dikes, flood diversion and detention projects, flood regulation reservoirs, river course harnessing, etc. combined with some non-engineering measures, such as soil conservation, flood warning and forecasting, fight against flood and emergency, flood insurance, etc., a system of flood control projects should be gradually established, with the Three Gorges Project as the mainstay and the dikes as the basis while the reservoirs on the tributaries, flood storage and diversion projects, river courses harnessing soil conservation and non-engineering measures playing supporting roles.

Based on the aforementioned principles of overall FCP, a great amount of manpowers and material resources have been put into the flood control constructions. As a result, the flood control standards have been improved and experienced the ordeals of several serious floods, including the one in 1998. Those principles have been proved feasible and correct. However, the original FCP is becoming unsuitable for the social and economic development of China in some aspects, which are,

a. ❄ Whether the human activities has affected the relationships between generality and focal points, left and right bank, upper and lower reach, for which careful research is imperative;
b. ❄ At present, the mainstream dikes of the middle and lower reaches of the Yangtze River are classified as three levels in the original FCP. Whether the levels of the dikes are still applicable along with the economic development. It also needs studies.
c. ❄ So far, there are many residents living in the flood diversion and detention areas, many of which under flood level and the safety construction seriously lagging behind. In case of flood diversion, the losses will be tremendous and the plan will have great difficulties to be carried out.
d. ❄ On the one hand, the limited investments retard the constructions of reservoirs on both the tributaries and mainstream; on the other hand, the projects planned in the original FCP are mainly power-oriented, the storage capacity for flood regulation is limited. Therefore, both the completed and planned projects are unsuitable for the increasing requirements for flood control.
e. ❄ Other engineering and non-engineering measures for flood control in the YRB are still vulnerable at present, which should be strengthened as an urgent task.

To sum up, there are still many problems in the system of flood control projects of the YRB, which have become very apparent based on the flood-fighting practices of 1996 and 1998. Therefore, it is necessary to revise and update the overall FCP of the YRB in accordance with the flood characteristics, current situations of flood control projects and the natural conditions and socio-ecnomic developments of the middle and lower reaches of the Yangtze River, so as to provide guidance for the construction of flood control projects and lay a solid foundation for the sustaining and stable development of the national economy.

3.2 Invest more capitals so as to complete all the projects already planned by the "*Report of the Yangtze River Basin Planning*"

Since the founding of our country, especially the reform and opening up drive, the

country, the local governments and the people have invested a lot of manpowers and material resources to construct flood control projects. The standards, though improved, are still lower than the targets defined in the "Report on the YRB Planning" and most of the planned projects have not been completed on schedule. Therefore, it is necessary to increase investments and formulate relevant policies to mobilize all parties. According to the planning of the YRB, more capitals should be invested to the following areas:

3.2.1 Enlarge the capacity of the rivers and lakes in transferring and storing flood waters

Firmly implementing the country's administration over post-flood rebuilding, the *Weiyuan*(protective embankments in lakeside areas) between the main dikes and among the lakes will be treated accordingly. For those key *Weiyuans* and the ordinary *Weiyuans* that protect important infrastructures, larger population and areas, the standards should be further improved. For those *Weiyuans* that are planned to be used for flood diversion and storage, safety construction should be well implemented based on the planning. For those *Weiyuans* that hinder the flood transfer and storage and are unfavorable for the regime of river, measures will be taken to safeguard the people's life and property as well as enlarge the capacity of the rivers and lakes in transferring and storing floods. The measures adopted are "remove the *Weiyuans* to transfer floods, return the farming lands to the lakes, provide work as a form of relieves, and resettle in new-built villages".

3.2.2 Strengthen the construction of dikes

According to the policy of "both storage and discharging should be considered, giving priority to discharging", the construction of dikes should be further strengthened to enlarge the discharge capacity of the river. In the middle and lower reaches of the Yangtze River, the total length of the dikes is about 30,000 kilometers, among which the dikes along the mainstream are approximately 3,600 km long. Such a length requires very large investments. Therefore, a unified construction plan should be drawn up and carried out by steps. First of all, all the dikes should be heightened and reinforced based on the design level defined in the *"Report on the Yangtze River Planning"*.

3.2.3 Accelerate the construction of flood regulation reservoirs

The "Comprehensive Utilization Planning of the YRB" finished in 1990 have outlined a complete planning for the reservoirs on the mainstream and tributaries of the upper reach and main tributaries of the middle and lower reach. However, both the completed and planned reservoirs have become unsuitable for the increasing requirements for flood control of the middle and lower reaches of the Yangtze River. According to the comprehensive harnessing policies of "both storage and discharging should be considered, giving priority to discharging" and "Store in the upper reach and dredge in the lower reach, the problems both on the surface and in the root should be tackled" as well as the development of social environment and national economy, the policies for reservoir construction should be modified in time, and flood control should be considered as the primary task in the arrangement of reservoir construction. For those reservoirs already completed or still under construction, schemes to increase

their flood storage capacity should be studied and carried out practically and effectively. The preparation works of the reservoirs with flood control significance should be speeded up.

3.2.4 Make greater efforts in the safety construction of the flood diversion and storage areas

According to the overall FCP of the middle and lower reaches of the Yangtze River, 50 billion m^3 flood water will be diverted in case of the 1954 type flood. At present, there are totally 40 flood detention and storage areas completed and planned, which has a total area of some 100,000 square kilometers and an effective volume of 50 billion m^3. As an effective measure to guarantee the safety of critical areas and reduce the losses, "both flood storage and reclamation" in these areas is an important part in the flood control system of the MLRY. Even though the control level for flood diversion rises and the TGP puts into operation in the future, which may result in reduced area and frequency to be used for flood storage, construction of these areas will be still indispensable. For this reason, it is fully necessary and urgent to carry out safety construction with a resolute mind and based on the requirements of "both flood storage and reclamation" in these areas. In the light of local conditions, the safety construction, with security areas and platforms as focal points, should be planned unifiedly and implemented by stages. In the short-term planning, safety construction should, at first, be carried out in those areas that are frequently used and can play major roles in flood control. As far as the long-term planning is concerned, necessary modifications will be made along with the changes in control level and the completion of the TGP.

3.2.5 Strengthen the construction of other engineering and non-engineering measures

Besides the engineering measures, other non-engineering measures must also be implemented and strengthened. These measures include: flood regulation commanding system, hydrology observation and transmission facilities, pre-flood basic works, enactment and execution of relevant regulations and laws related to the flood control, management of the river course and flood diversion areas, flood forecasting and warning, chief-executive-responsible commanding systems and flood-fighting organizations at different levels, etc..

3.3 Further strengthen the construction management of the flood control projects and reinforce the water resource administrative functions of river basin organization

The flood control projects are scattered in large areas, so how to strengthen the construction management has always been highly emphasized by the central and local governments. Nevertheless, due to various reasons, both objective and subjective, the collapse of the Jiujiang Dike inevitably happened in the 1998 flood. Though the gap was successfully blocked under joint efforts, it still caused great losses to the people's lives and properties. The experiences and lessons tell us, legal body responsibility, tender and supervision mechanism must be introduced in the construction of flood control projects. Meanwhile, the river basin organizations, entrusted by the central government, must participate in the legal bodies as well as the whole process of

management from design, construction to acceptance. This is of practical significance for the control of costs, schedule and quality.

3.3.1 Strengthen the management of preliminary works, strictly follow the construction programs

The preliminary works must be carried out in strict accordance with the construction programs because, as the cornerstone, it concerns the success or failure of a project. First of all, the qualification of the work unit, which undertakes the preliminary works of a project, must be assured. The preliminary works of independent projects should be carried out by qualified work units, and that of the key projects should be done by the river basin organizations. Design supervision should be put into practice to ensure the quality of design. Moreover, the design results of different stages should be strictly examined and checked by the Ministry of Water Resources or the river basin organizations.

3.3.2 Reinforce the legal body responsibility, tender and supervision mechanism

Management is the essential element in project construction; therefore, the mechanism of legal body responsibility, tender and supervision must be reinforced. The extent of jurisdiction should be defined. The river basin organizations and provincial water resource administrative departments should take the responsibilities of important and other ordinary projects accordingly, then the legal bodies, consisted of river basin organizations, related departments at different levels of province, region and county, should be teamed up and responsible for the projects. During the organizing of the legal bodies, the river basin organizations and provincial water resource administrative departments should play a leading role. The work units of construction should be decided through tendering. During construction, comprehensive supervision should be carried out by professional units with corresponding qualifications and authorities. The professional units of the river basin organizations should be in charge of the supervision of key projects and take part in other projects, so as to strengthen the control of quality and acceptance in projects construction.